# INTEGRATED HYDROLOGICAL MODELLING FOR KODAVANAR RIVER BASIN USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM (GIS)

**A SYNOPSIS**

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**(Reg. No. 201405212)**

*in partial fulfilment for the award of the degree*

*of*

**DOCTOR OF PHILOSOPHY**

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**TAMIL NADU, INDIA**

**APRIL 2023**

## 1. INTRODUCTION

Life does not exist without water on earth, but water is a renewable resource. In the current scenario, the amount of water requirement is progressing because of population explosion, urbanization, globalization, and industrialization. On the other hand, the demand for food has also been increasing, which directly depends on water sources [1]. In India, a drought-prone country compared to other countries, the human population increases every decade by 1210.19 million as per the 2011 Census [2]. Hence, the demand for sustainable development among the people depends upon food production, industrialization, and urbanization. Even though India is a subcontinent with three perennial rivers in the North and North-Eastern parts, the Western and southern parts always face water scarcity, even for domestic purposes, especially in the non-monsoon seasons [3].

According to the Central Water Commission report, India had an average rainfall of 1105 mm [4]. Despite needing 3000 billion cubic meters of water, India receives 4000 billion cubic meters of rainfall during monsoon seasons, but India conserves only eight percent of it [5]. Due to the non-availability of sufficient water conservation systems, India lost approximately 92 percent of water received from rainfall. Even though the State of Tamil Nadu has received rainfall in two rainy seasons, many major cities like Chennai, Madurai, Dindigul etc., faced acute water scarcity during summer [6].Dindigul District is situated between the Western Ghats and Sirumalai hills and does not have a major river basin in this district. In the Dindigul district, 9 dams and sufficient ground water recharging structures are also available even though the ground water level depletes yearly.

Persistent groundwater pumping is the primary source of groundwater exhaustion, which has adverse consequences, such as reservoirs running dry, water levels dropping in nearby bodies of water, the degradation of water quality, and an upsurge in pumping costs and land subsidence. Groundwater depletion commonly occurs because of the frequent pumping of water [7]. Therefore, the aquifer does not have enough time to replenish itself, and many other factors are also involved. The reason for water scarcity must be accomplished scientifically, considering the soil types, geological formations, and geomorphology. But, the feasibility of constructing a real-

time structure for scientific findings is time-consuming and involves huge investments. So that modelling techniques can be used for trial-and-error studies and decision-making. Modelling is intergraded with Remote Sensing (RS) and Geographical Information System (GIS) methods, advanced tools widely employed in the water resource sector for making decisions. Therefore, in this research, the parameters influencing the groundwater potential are assessed utilizing RS and GIS methodologies and examining the integration of surface and groundwater-related studies to conserve water for efficient water management.

In this research, the researcher focused on analysing the factors influencing groundwater potential, examining the decadal LULC changes of the upper Kodavanar River basin, developing an NRCS – CN model for Runoff quantity prediction from drainage systems, predicting the potential groundwater area, the Groundwater Recharge zone and analysing the effect of the Groundwater Quality Index.

## 1.1 MOTIVATION FOR RESEARCH

There is a need to conserve the water at the source itself for sustainability and cost-effectiveness. Groundwater depletion is mainly due to the continuous exploitation of ground resources to fulfil the human, crop, and animal demand for water. The feasibility of constructing a real-time structure for scientific findings is time-consuming and involves huge investments. So that modelling techniques can be used for trial-and-error studies and decision-making. Modelling is intergraded with Remote Sensing (RS) and Geographical Information System (GIS) methods, which are advanced tools widely employed in the water resource sector for making decisions.

## 1.2 STUDY AREA

Kodavanar sub-basin is a major portion of the Cauvery River basin. The research field lies in “Dindigul District” and shares a smaller part in Karur District. The aerial extent of the research field is 2591.65 $km^2$ (Figure 1). The Kodavanar sub-basin lies between “North latitudes 10º09’56.70” and 10º52’31.50”; The East longitudes 77º37’29.29” and 78º13’14.21”. The Kodavanar River originally started from the hills and can connect all other parts in three directions. The area chosen for examination has

a climate of sub-tropical. The plain areas' mean maximum temperature in the research area was 36.5ºC to 41.8ºC, and the mean minimum temperature was 17.4ºC to 24ºC. In Hilly areas mean maximum temperature was 7.9ºC to 28.8ºC, and the mean minimum temperature was 6.0ºC to 8.5ºC. The annual average rainfall is 898mm.

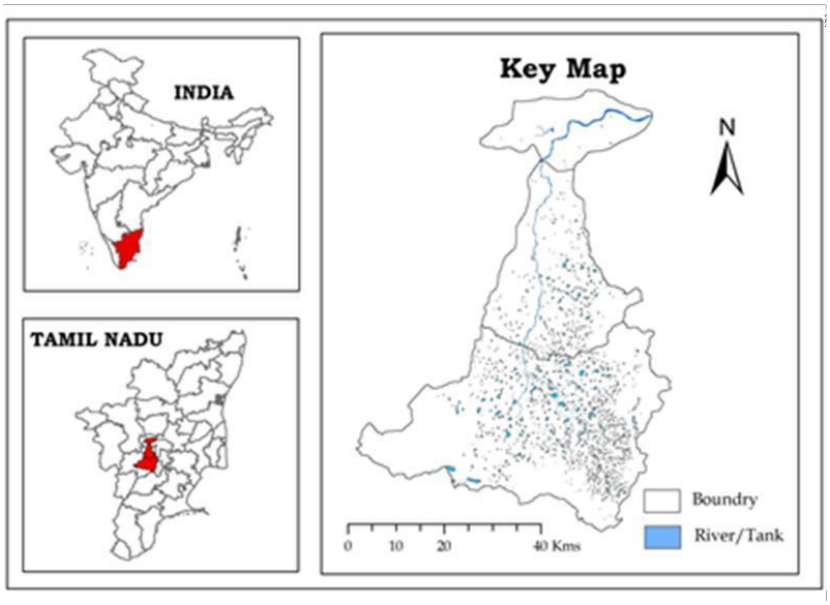


**Figure 1** Study Area Kodavanar River basin

## 2. LITERATURE REVIEW

The survey was conducted to create a clear empirical methodology to assess and prioritize the Artificial recharge zone utilizing RS and GIS. The chapter, literature review, is structured under the following sub-headings.

1. Morphometric analysis
2. Decadal Land Use Land Cover (LULC) variations employing RS and GIS
3. Estimation of Surface runoff utilizing NRCS – CN technique using RS and GIS
4. Detection of Groundwater potential zone employing RS and GIS

### 2.1 MORPHOMETRIC ANALYSIS

Utilizing mathematical formulas, morphology is the study of the structure, like size and shape, of the hydrological system on the planet's surface by Kaliraj et al. [8]. Each hydrologic layout is unique since every site has a particular set of physical elements that influence the layout. Such elements may be broken down into

morphological characteristics, atmospheric factors, land use patterns, and variables relating to the soils. Rekha et al. [9] analysed the subsequent characteristics have been subjected to morphometric analysis: “bifurcation ratio (Rb), (linear parameters), basin relief (Bh), relief ratio (Rh) and ruggedness number (Rn) (relief parameters) and drainage density (Dd), stream frequency (Fs), texture ratio (T), form factor (Rf), length of overland flow (Lof), constant channel maintenance(C) (aerial parameters)”. It is now virtually universally accepted that there is a link between different drainage characteristics and certain variables like weather, geology, geomorphology, and morphology by Horton [10], Strahler [11], Melton [12], Pakhmode et al. [13]. Nautiyal [14] suggested the photo-interpretation method takes less time than real field investigations and may provide useful data when combined with field inspection. The GIS method is an accurate, quick, and affordable approach to carrying out a morphometric study by Kaliraj et al. [15]. Based on toposheets (SOl) and satellite images, a base map with drainage features has been created for the current investigation. Nag [16]. RS combined with GIS approaches is an effective tool for drainage delineation and upgrading for morphometric analysis by Patel et al. [17]. It is derived from the above review based on the hydrological analysis various factors like linear and relief, and aerial aspects are considered for the study. Most of the literature has not considered all factors like linear aspects, aerial aspects, relief aspects, and other factors for analyzing river basins. Most of the morphometrical studies are done manually so that time consumption is more. Limited literature used the Geographical Information System as a method for morphometric examination. GIS tool is a more accurate tool for morphometric analysis. Mostly, it used a survey of India Toposheet for morphometric analysis. Few studies were done on the entire river basin as a study area for morphometric analysis.

## 2.2 DECADAL LULC VARIATIONS EMPLOYING RS AND GIS

Prakash et al. [18] suggested the recent methods for tracking environmental changes and preserving natural resources now include LULC change as a key and crucial element. Bundeli et al. [19] examined in the study of global trends, the effects of LULC on the ecosystem's viability are becoming increasingly crucial. The “maximum likelihood supervised classification” methodology was utilized to extricate data from the satellite image, and a post-classification variation recognition system was

used to identify and track changes in LULC by Dewan et al. [20]. Two crucial factors that influence every region's hydrological behaviour are LULC and climate. Organizers, resource managers, researchers, and decision-makers must use LULC categorization to successfully regulate environmental and life circumstances. The preparatory information, such as survey information, topographic information, essential evidence obtained from the surrounding population, and assessing current circumstances, play a significant role in analysing change detection between historical and present LULC. RS is crucial to make and recording the real changes in LULC on a regional and global scale. On the satellite pictures from 1987 to 2001, the researchers conducted supervised classification and post-classification variation identification. The accuracy evaluation and categorization of land cover classes were based on six field trips and the 1987 land cover map. The main findings were the research area's waterlogging and vegetation deterioration by Shalabh et al. [21]. With the use of cutting-edge software technology called GIS, the advancement of RS plays a vital role in risk assessment, warning systems, surveillance, and mapping. The maximum-likelihood classification approach uses the likelihood of the contours surrounding the training region to allocate the unidentified pixels to a particular class. Calculating the likelihood that a pixel belongs in a particular class is done on the assumption that the statistical value for each class in each band is regularly spread. The class with the greatest probability receives each pixel.

According to the evaluated literature, investigators assumed a single urban built-up LULC class that produced a very higher CN number. Utilizing high-resolution RS data, such class may be enhanced with level 3 or level 4 urban LULC classes, providing more influence over CN numbers in this region. The number of decades for comparing the changes and forecasting the future is limited. Usually, the planners need more decadal LULC changes for a better understanding of the factors involved in the changes that occurred. Most of the studies arrived at the reason and the scale for the groundwater flow and were not used to solve specific issues for decision support lack of consideration for all factors related to LULC change identification utilizing RS and GIS.

## 2.3 ESTIMATION OF SURFACE RUNOFF UTILIZING NRCS – CN TECHNIQUE

When soil is fully absorbed, and extra water from rain, meltwater, or other sources runs over the ground, this is known as surface runoff. This shows a substantial part in the hydrologic cycle. When the amount of rainfall on a surface exceeds the rate at which water can penetrate the ground and any depression storage has already been full, infiltration overflow overland flow develops. Runoff is a by-product of rainstorms, and its amount and frequency depend on the rainfall event's features, such as its intensity, length, and dispersion. In addition to these aspects of rainfall, several catchment-specific elements directly affect the frequency and amount of runoff. This includes the catchment type, slope, and plant cover of the soil. As the functionality of soil kind and land use, Curve Number (CN) offers an empirical correlation for calculating initial abstraction and runoff. Recently, researchers have been more engaged in GIS and RS methodologies because they make it easier to estimate runoff from watersheds by Melesse et al. [22]. The National Resources Conservation Service (NRSC) coined the term "HSG". NRSC divided soil types with similar physical attributes and runoff traits into designated HSG groupings. Gitika et al. [23] recommended Hydrological modelling in GIS using RS technologies as a strong system study technique for runoff production in geo-hydrologic settings. U.S. Department of Agriculture (USDA) (1986) devised a categorization system in which the soils are divided into 4 classes, A, B, C, and D, to better study infiltration characteristics.

Based on data from the infiltrometer, runoff, and estimated rainfall, distinct groups of soils were allocated. The soil's AMC describes how much moisture is available in the soil at any particular moment. It is based on the total quantity of rainfall during the five days before a rainy event by McCuen et al. [24]. USDA (1986) developed three AMC conditions (AMC I, II, and III) depending on multiple soil properties and rainfall limitations for the inactive and growth stages. AMC I, II, and III conditions, correspondingly, imply low, medium, and significant runoff potentials.

The literature studies show that stormwater management systems predict the high flood area and reduce waterlogging during the rainy season. The minimum study only considers Identifying the exact location for water logging places and high flow.

Less than several studies are available for the calculation of runoff models utilizing RS and GIS. Many researchers do not consider all factors like rainfall, temperature, Relative humidity, LULC, Soil, and slope. The studies show that runoff estimate using NRCS – CN method is very effective in the small watershed area. In larger watersheds, the calculation of CN is not more difficult. The delineation of hydrological soil group classification classes A, B, C, and D directly influenced the soil's infiltration rate.

## 2.4 IDENTIFICATION OF GROUNDWATER POTENTIAL ZONE USING REMOTE SENSING AND GIS

Jhariya et al. [25] suggested Groundwater degradation is mostly caused by uncontrolled groundwater extraction and insufficient aquifer recharge in various places around the globe. As a result, groundwater conservation and watershed-level preservation have become more crucial globally. Modern methods like RS and GIS are useful for managing natural resources. Combining these methods is beneficial for evaluating, tracking, and preserving groundwater. They are also often used to delineate potential groundwater areas and have grown in popularity due to groundwater availability. Ali et al. [26] disclosed Demarcating groundwater potential areas may employ many approaches, including geologic, hydrologic, geophysical, and RS technologies. The analytical hierarchy process (AHP) and GIS methods were combined to create groundwater potential areas depending on 12 factors, including "geomorphology, hydrogeology, lineament density, soil texture, drainage density, slope, rainfall, topographic wetness index, roughness, topographic position index, curvature, and LULC" by Yildrim et al. [27], Allafa et al. [28]. The resultant groundwater potential map was already separated into three categories: good, moderate, and poor.

Different types of literature reveal that combining RS and GIS tools is highly efficient in groundwater potential identification research. Most studies do not consider the surface and sub-surface characteristics together for better understanding and making. Some of the Studies only used high-resolution Remote sensing data. The others used low-resolution satellite images. Many studies used weights assigned through Satty's Analytic Hierarchy Process (AHP) method and GIS environment. This method gives more accurate use for identifying potential groundwater zone. Minimum factors

used related to groundwater potential Zone. They are not considering all factors like geology, geomorphology, LULC, soil, lineament, and drainage.

## 2.5 AIM

This study intends to examine the Artificial Groundwater Recharge Zone in the Kodavanar River basin by integrating RS and GIS.

## 2.6 RESEARCH OBJECTIVES

1. To analyze the factors influencing Groundwater potential utilizing RS and GIS.
2. To examine the decadal LULC changes of the upper Kodavanar River basin utilizing RS and GIS.
3. To develop an NRCS – CN model for Runoff quantity prediction from drainage systems.
4. To predict the potential groundwater area and prioritize the groundwater recharge zone and analyse the effect of the Groundwater Quality Index.

## 3. DATA USED

The following data are collected for the study. The Landsat satellite data in different sensors like "Multispectral Scanner (MSS), Enhanced Thematic Mapper (ETM), Thematic Mapper (TM), and Operational Land Imager (OLI) sensor" are collected (Table 1). The False Colour Composite images are utilized for this study.

**Table 1:** Satellite Data

| SATELLITE | SENSOR | DATE OF ACQUISITION | SPATIAL RESOLUTION (m) | SPECTRUAL RESOLUTION | BAND USED |
|---|---|---|---|---|---|
| **Landsat 8** | MSS | 27.10.1973 | 60 | 7 Bands | B2,B3,B4 & B5 |
| **Landsat 8** | MSS | 22.10.1981 | 60 | 7 Bands | B2,B3,B4 & B5 |
| **Landsat 8** | ETM & TM | 05.10.1997 | 30 | 11 Bands | B4,B5,B6 & B7 |
| **Landsat 8** | OLI | 07.11.2010 | 30 | 11 Bands | B4,B5,B6 & B7 |
| **Landsat 8** | OLI | 23.10.2021 | 10 | - | - |

From 1973 to 2021, meteorological information like rainfall, temperature, and relative humidity was obtained from the ground and surface water division, Taramani, Chennai, for the past five decades.

### 3.1 SOFTWARE USED

**a) Aeronautical Reconnaissance Coverage GIS (ArcGIS)**

The ArcGIS range of client software was created and managed by Esri.ARC/INFO, a command-line-oriented GIS platform for data manipulation, was initially released in 1999 as ArcGIS. After ARC/INFO merged into ArcGIS Pro in 2015, ArcGIS Desktop was replaced by ArcGIS Pro.

**b) Earth Resources Data Analysis System (ERDAS)**

Erdas Imagine is a software program for image processing that can handle geographical and alternate imagery and vector information. Erdas may be utilized with other GIS and RS programs, and a wide range of other programs shall read the imagery storage pattern.

## 4. STUDY1: TO ANALYZE THE FACTORS INFLUENCING GROUNDWATER POTENTIAL UTILIZING RS AND GIS

### 4.1 GEOMORPHIC FEATURES

The layout of the planet's surface, as well as the size and shape of its landforms, is studied via measurements and computational equations in morphology. The examination includes the study of river basins to understand their performance better. The places where the water enters the landform area are called river basins, where water flows in a specified direction. Source the conservation of water we utilize Remote Sensing and GIS so that water wastage can be avoided Various aspects of analysis (Figure 2). They are

1. Linear Aspects
2. Aerial Aspects
3. Relief Aspects

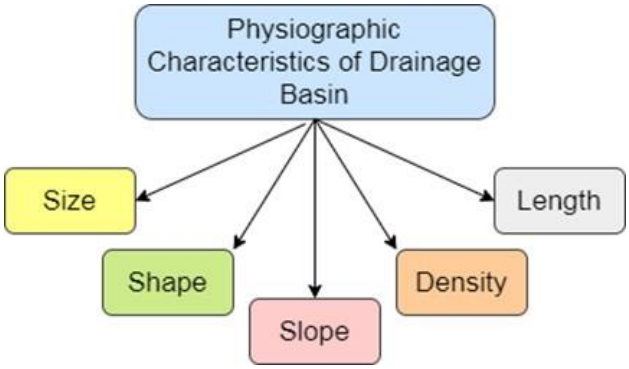


**Figure 2:** Physiographic Characteristics of Drainage Basin

## 4.2 MORPHOMETRIC ANALYSIS EVALUATION METHODS

The overall length of stream segments is higher in first-order streams and reduced with the progression in stream order. RL is increased with the progression in stream order,.1st and 4th order deviated slightly due to the erosional effect. So, soil loss will lead to reducing infiltration and water holding capacity. The bifurcation ratio is 2.273. It shows the normal watershed category, meaning waterfalls in and drains of it go to a common outlet. The most substantial independent factor influencing the physiographic and hydrologic evolution of drainage basins is overland flow. The value is 0.307 Km/km$^2$, which shows quicker surface runoff that leads to reduced infiltration capacity, and flash floods may occur. Drainage density and stream frequency are direct relations to surface runoff. The constant of channel maintenance (C) is the reciprocal of the drainage density. It shows low runoff, the maximum covered by agricultural and barren land, low relief, and highly permeable subsurface soil (Table 2)

Form factor and circulatory ratio are low. It shows the shape of the basin is strongly elongated. It is easy to manage that the flow velocity may moderate to enter the subsoil. The elongation ratio is between 0.6-0.9. It denotes a steep slope and higher relief of the region, which means soil erosion, flash flood, and less groundwater recharge on the river course. Drainage Texture is high and represents a very coarse drainage texture type.

The compactness constant is directly proportional to the erosion risk analysis element. This study shows moderate risk and the need for conservation measures. The relief ratio shows the basin's entire steepness and erosion intensities. This basin measures a 2% Relief ratio, which denotes the basin's gentle slope, so the flow velocity

is moderate, leads to soil erosion, and affects groundwater recharge. In Ruggedness number, slope, and length characteristics are combined. The maximum indicates high basin relief that leads to flash floods and reduces infiltration through the soil.

**Table 2:** Evaluation Methods for Morphometric Analysis

| Aspect | Morphometric Parameters | Definition / Formula | References |
|---|---|---|---|
| Linear Aspect | Stream order (Nu) | Hierarchical order | Strahler (1964) |
| | Bifurcation ratio (Rb) | Rb = Nu/Nu+1 where Nu = total no. of stream segments of order 'u', Nu+1 = number of segments of the next higher order | Schumm (1956) |
| | Length of main channel (Lm) | Length along longest water course from the outflow point of to the upper limit of catchment boundary Length of the stream of order u (Lu) Length of the stream | Horton (1945) |
| | Mean stream length (Lsm) | Lsm = Lu/Nu | Strahler (1964) |
| | Stream length ratio (RL) | RL = Lu/Lu1 where Lu = total stream length of order 'u', Lu1 = the total stream length of its next lower order | Horton (1945) |
| | Length of overland flow (Lg) | Lg = 1/D * 2 where Lg = length of overland flow, D = drainage density | Horton (1945) |
| | Basin length (Lb) | Distance between outlet and farthest point on the basin boundary | Ratnam et al. (2005) |
| | Basin perimeter (P | ) Length of watershed divide which surrounds the basin | Ratnam et al. (2005) |
| Areal aspect | Basin area (A) | Area enclosed within the boundary of watershed divide | |
| | Drainage density (D) | D = Lu/A | Horton (1932) |
| | Constant of channel maintenance (C) | C = 1/D | Schumm (1956) |
| | Stream frequency (Fs) | Fs = Nu/A | Horton (1932) |
| | Circulatory ratio (Rc) | Rc =4* Pi * A/P2 | Miller (1953) |
| | Elongation ratio (Re) | $Re = \sqrt{((4\ X\ A))}/Pi/Lb$ | Schumm (1956) |
| | Form factor (Rf) | Rf = A/Lb2 | Horton (1932) |
| | Compactness constant (Cc) | Cc = 0.2821P/A0.5 | Horton (1945) |
| | Drainage texture (Rt) | Rt = Nu/P | Horton (1945) |
| Relief aspect | Total relief (H) | Maximum vertical distance between the lowest and highest points on the valley floor of a watershed | Hadley &Schumm (1961) |
| | Relief ratio (Rh) | Rh = H/Lb | Schumm (1956) |
| | Ruggedness no. (Rn) | Rn = H * D | Melton (1957) |

## 5. STUDY 2: TO ASSESS THE DECADAL LULC CHANGES OF THE UPPERKODAVANAR WATERSHED USING RS ANDGIS.

### 5.1 LULC CHANGES

Land cover refers to the biophysical aspects of the land surfaces, whereas LULC refers to the human use of the land. To have effective maintenance, application, and preservation of water sources, research on LULC Changes is undertaken.

### 5.2 PRE-PROCESSING

Data extrication, picture augmentation, data integration and mosaicking, categorization, map construction, geo-coding, vector data handling, and 3D tools like Virtual GIS covered among the image processing operations accessible in the ERDAS Imagine software. Geometric Correction: Imagine can register one image to another or a map projection to an image. For comparing or integration, images are co-registered with each other. The temporal Landsat images at a decadal timeframe (1973, 1981,

1997, 2010, and 2021) enclosing the whole watershed were utilized together with the "Shuttle Radar Topography Mission (SRTM) 30 m digital elevation model (DEM)" in the current research. The parameters of the satellite information employed are provided in the table. Furthermore, various alternate datasets are utilized for demographic (population), rainfall assessment, and soil maps for hydrologic soil group preparation.

The total region covered by the built-up area was estimated at 7.7 $km^2$ in 1973 and increased to 232 $km^2$ in 2021. Based on this study, the area of water bodies was 9.24 $km^2$ and 21.6 $km^2$ in 2021. As per the study, the forest sector covered 332 $km^2$ and identified no drastic change in the five decades. The number of very high rainfall events has increased from 14.56mm to 78.8mm, as evidenced by the present assessment of rainfall, urban development, and LULC variation during the last 50 years, and exponential urban and population development. Urban flooding is likely to become more common as land use intensifies and the likelihood of additional high rainfall events increases.

## 6. STUDY 3: TO DEVELOP THE NRCS – CN MODEL FOR RUNOFF QUANTITY ESTIMATE FROM DRAINAGE SYSTEMS

### 6.1 HYDROLOGICAL SOIL GROUP

The "Natural Resource Conservation Service" divides soils into 4 Hydrologic Soil Groups depending on their runoff capacity. A, B, C, and D are the four Hydrologic Soil Groups. Group A soils possess the maximum infiltration rate and the minimum potential runoff, and group D soils possess the minimum infiltration rate and maximum runoff potential. Soil cover complexes and their related runoff curve numbers are determined by soil Hydrologic Groups (HSG), land use, management techniques, and hydrologic conditions.

### 6.2 RUNOFF ESTIMATION UTILIZING NRCS TECHNIQUE

The "NRCS-CN (Natural Resource Conservation Service-Curve Number)" is a very famous and broadly employed technique of calculating rainfall excess from rainfall and depends on only one specification, i.e., CN. The NRCS-CN framework is utilized in the current research to calculate the urban runoff potential employing Landsat time-series (1973–2021) information as given in Equations 1 – 3.

$$Q = [(P-Ia)^2 / (P-Ia+S)] \quad (1)$$

$$S = [(25400-254) / (CN\ (I, II, II)] \quad (2)$$

$$Ia = 0.2\ S \quad (3)$$

Where,

Q = Runoff (mm); Ia = Initial abstraction; S = maximum retention capacity.

P = Rainfall (mm).

The runoff analysis utilizing NRCS-CN shows a substantial rise during the above timeframe, mainly in urban regions. In 1973, the settlement was 0.50%, and the Runoff was 11.37mm. For the year 1981, the settlement was 10%, and the Runoff was 16.98mm. In 1997, the settlement was 10.80%, and the Runoff was 26.3mm. For the year 2010, the settlement was 11.80%, and the Runoff was 54.2mm. In the year 2021, the settlement was 15.10%, and the Runoff was 72.9mm. In Dindigul district, the situation is identified to be very alarming since very higher runoff has progressed from 11.38mm to 72.9mm.

## 7. STUDY 4: TO PREDICT THE GROUNDWATER POTENTIAL ZONE AND PRIORITIZE THE GROUNDWATER RECHARGE ZONE AND ANALYZE THE EFFECT OF THE GROUNDWATER QUALITY INDEX.

### 7.1 METHODS FOR ASSESSING GROUND WATER PROTENTIONAL ZONE REMOTE SENSING BASED METHODS

a) Weighted overlay method (WOM)

b) Frequency ratio model (FRM)

c) Weighted aggregation method (WAM)

d) Analytical hierarchical process (AHP)

The generation of several thematic maps includes Geology, Drainage Density, Slope, LULC, Lineament density, and Geomorphology. Ranks are assigned for Geology lineament density 9th rank, Geomorphology, and LULC 8th rank, and remaining thematic maps are assigned 7th rank. After that, the researcher assigned the weights for every thematic map based on the literature study and the relative importance of the study. Finally, the researcher calculated the final weightage for each layer, and the

weighted layer was created. The Rainfall data and soil Texture characteristics also influence the identification of the Groundwater Recharge Zone. The overall weights and ranks of various polygons in the combined unit were obtained from the subsequent formula to attain the groundwater potential index as shown in equation 4.

$$GWPI = \{[(GMw)(GMr)] + [(GGw)(GGr)] + [(SLw)(SLr)] + [(LUw)(LUr)] + (DDw)(DDr)] + [(LDw)(LDr)] + [(RFw)(RFr)] + [(STw)(STr)]\} \quad (4)$$

Where "GWPI is the groundwater potential index, GM denotes geomorphology, GG denotes Geology, SL is the slope, LU is land use/ Land cover, DD represents drainage density, RF is rainfall, ST denotes soil texture, w is weightage, and r is rank".

The resulting map is separated into high, moderate, and low groundwater potential areas. The aerial spread of such divisions is 749 $km^2$, 1363 $km^2$, and 479 $km^2$ respectively. As can be observed from the image, lowland and midland areas are the primary locations of intermediate groundwater potential areas. Higher rainfall areas with higher infiltration ability are often restricted to higher groundwater potential areas. The valleys and regions with heavy drainage densities are often where the intermediate groundwater potential areas are found. Zones with poor groundwater potential are mostly found in highlands and lowlands, while they are found much less often in the Midlands. The findings of the Central Ground Water Board's CGWB) observation well information is utilized to additionally cross-validate the potential groundwater areas identified in the current research (Table 3).

**Table 3:** Area for groundwater recharging Zones

| S.No | Level of Recharging Groundwater and its Possible Zone | Area($km^2$) |
|---|---|---|
| 1 | Good | 24.67 |
| 2 | Extreme good | 21.25 |
| 3 | Normal | 48.7 |
| 4 | Better | 59.22 |
| 5 | Poor | 69.71 |

# 8. CONCLUSION

## 8.1 MORPHOMETRIC ANALYSIS

1. Every hydrological research requires a morphometric examination of the drainage network as a precondition. Therefore, it is crucial to understand how stream systems behave and interact with one another in several studies of water sources.
2. It has been shown that GIS methods and RS satellite information are useful instruments for drainage characterization.
3. The Kodavanar River basin's morphometric assessment has been defined in the current article depending on a number of drainage characteristics employing RS satellite information and the most recent GIS drainage analytical techniques.
4. The Kodavanar River is assumed to be a member of the fourth-order basin. Lower-order streams predominate in the Kodavanar basin. Measurements of basins' linear, aerial, and relief characteristics are used to do the morphometric assessment.

## 8.2 DECADAL LULC CHANGES

1. The structural, biochemical, and ecological features of a river basin are significantly impacted by LULC changes.
2. The drastic LULC variation in the Kodavanar river basin, between 1973 and 2021 showed that agricultural land diminished due to water availability factors, etc.
3. Water bodies in the earlier decades were 9.24 $km^2$ and slowly declined due to population explosion and over-exploitation of water by industries.
4. The total area covered by the built-up area was estimated at 7.7 $km^2$ in 1973 and increased to 232 $km^2$ in 2021.
5. The RS and GIS method was very efficient in detecting the changes between different decades. It was the very tool for change detection.

## 8.3 RUNOFF ESTIMATION USING NRCS – CN METHOD USING RS AND GIS

1. Land use, and topographical variables, including slope and aspect, soil texture, and soil organic matter, are just a few elements that impact surface runoff. These

variables can affect the rate, water holding capacity, and soil features like texture and soil organic matter.

2. RS images are important and useful instruments for tracking and estimating environmental phenomena and providing crucial data on the kind of land use. Hence, utilizing the NRCS-CN framework, the combination of soil attributes and RS data.
3. In 1973, 1981, 1997, 2010, and 2021, the runoff was 11.38mm, 16.98mm, 26.3mm, 54.2mm, and 72.9mm, respectively
4. The need to improve surface runoff water storage efficiency and develop water harvesting techniques to potentially utilize this water for sustainable agricultural growth.

## 8.4 DETECTION OF GROUNDWATER POTENTIAL ZONE AND RECOMMEND ARTIFICIAL RECHARGE STRUCTURES

1. RS and GIS have proved to be stronger and more cost-efficient methods for identifying potential groundwater zone in the Kodavanar River basin.
2. According to the research, the combination of 6 thematic maps, including those of drainage density, slopes, geology, geomorphology, lineament density, LULC, and soil, provides local officials and managers with knowledge about the places that are favourable for conserving water.
3. The specified research region is divided into 3 potential groundwater regions: high, moderate, and low.
4. Such groundwater potential data shall be helpful for the efficient detection of favourable regions for artificial recharge techniques.
5. The aerial spread of these categories is High –;749 $km^2$, Moderate -; 1363 $km^{2,}$ and, Low -; 479 $km^2$.

## 9. ORGANIZATION OF RESEARCH

The proposed research work is organized as follows; the thesis structure includes the following Eight chapters. The main aim of the research is water conservation and the prioritization of an artificial recharge zone of groundwater for the Kodavanar river basin in the Dindigul district.

**Chapter 1:** This Chapter provides a general introduction deal with the introduction about the main aspects of water resources and components of the hydrological cycle, identification problems, key problems associated with water sources, the motivation of the research, the scope of the research, and the main objectives of the research.

**Chapter 2:** It explains the investigations previously related works to Morphometric analysis, Decadal LULC Changes utilizing RS and GIS, Calculation of Surface runoff employing NRCS – CN technique using RS and GIS, and detection of Groundwater potential Zone utilizing RS and GIS.

**Chapter 3:** This chapter provides the research methodology for the current research in detail. It describes the overall flow and data collection.

**Chapter 4:** This chapter explains the morphometric analysis of every zone by using GIS to develop groundwater capacity.

**Chapter 5:** This chapter deals with decadal changes in the Kodavanar River basin utilizing RS and GIS and explains the estimation of surface runoff in the Kodavanar River basin using the NRCS – CN method in geospatial methodology.

**Chapter 6:** This chapter explains the detection of groundwater potential zone in the Kodavanar River basin employing RS and GIS.

**Chapter 7:** This chapter deliberates on the results and discusses prioritizing the artificial recharge zone and recommendations for the artificial recharge patterns in the investigation region.

**Chapter 8:** This chapter reveals the overall conclusion, recommendations and future work.

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